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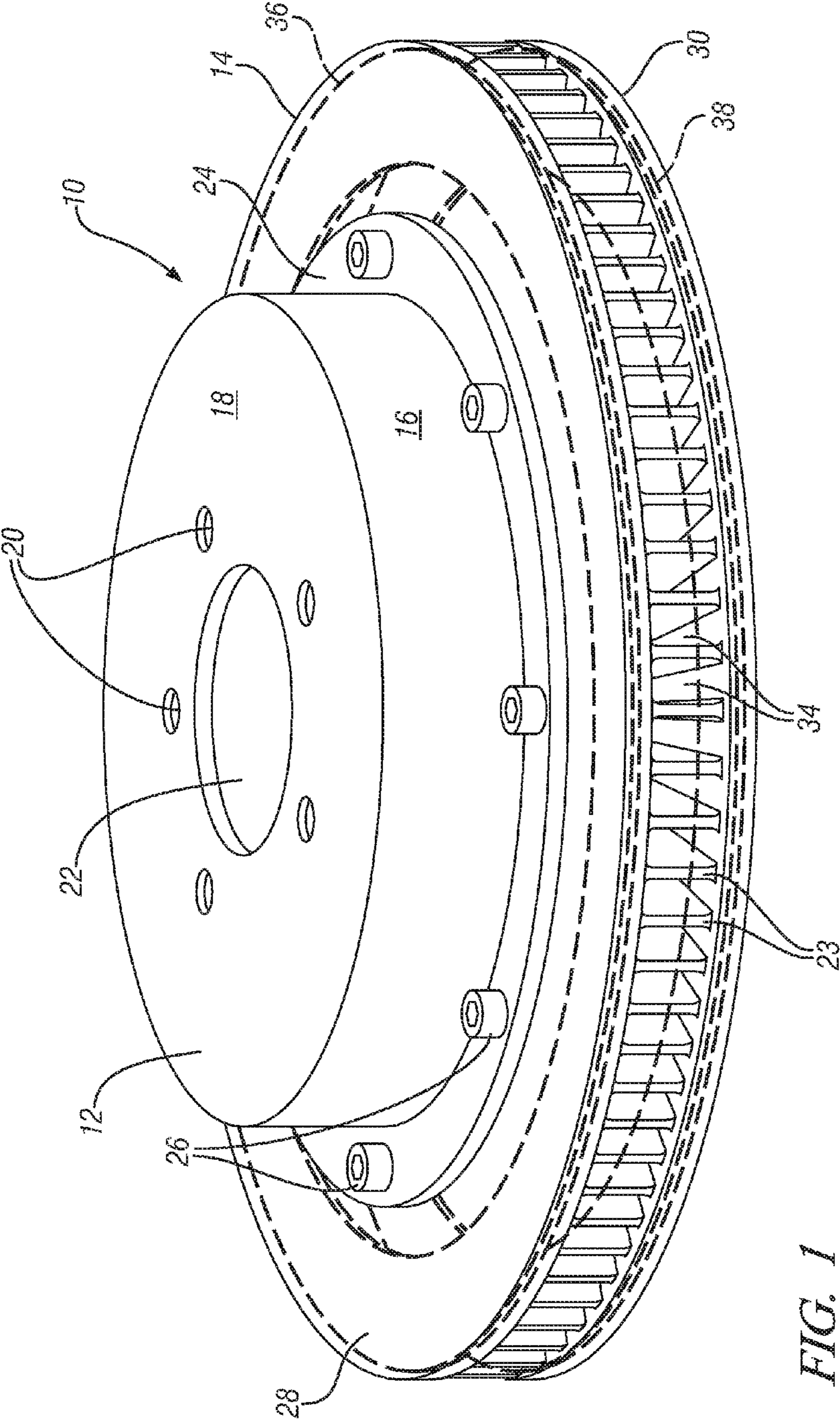


FIG. 1



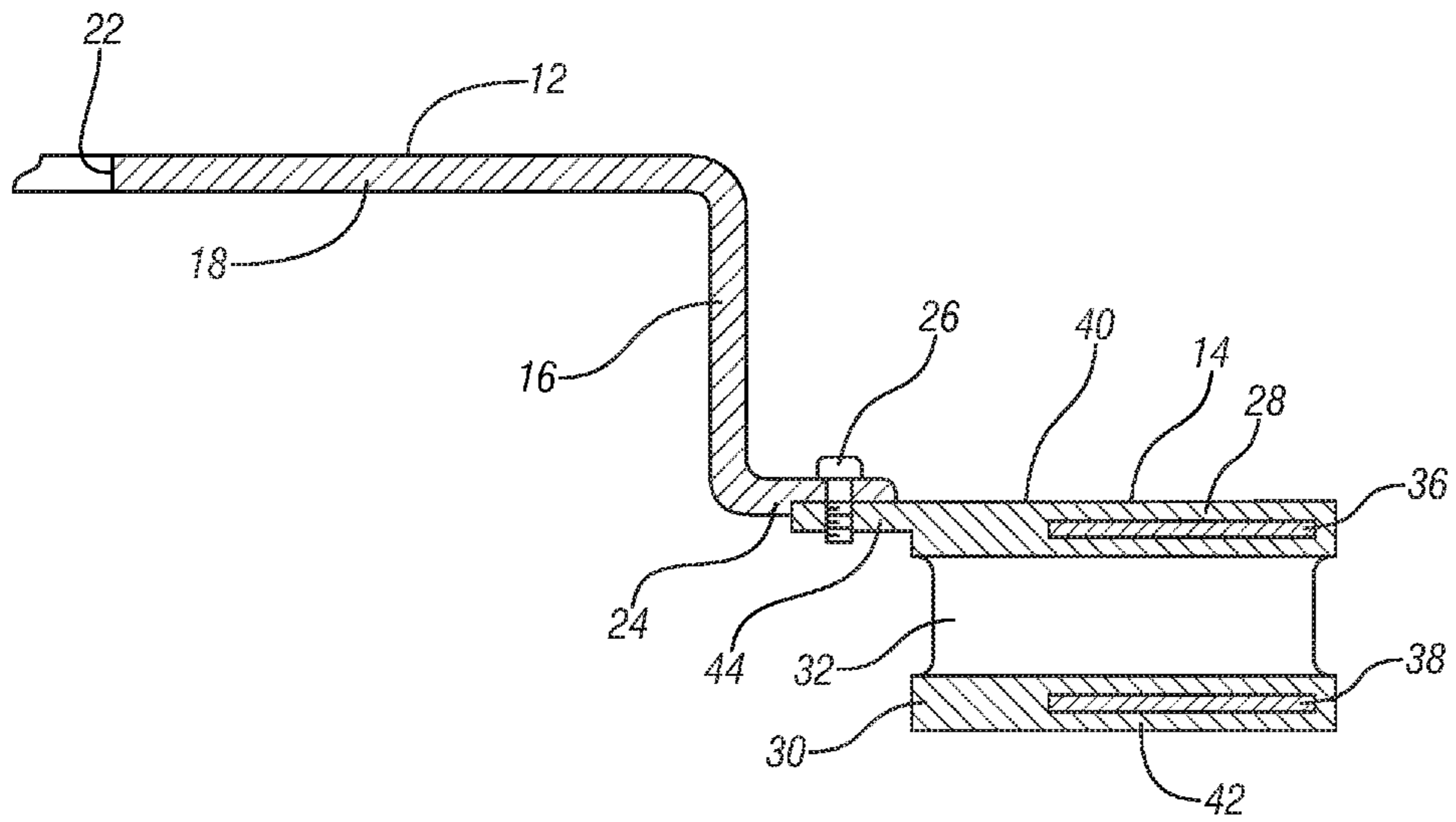


FIG. 2

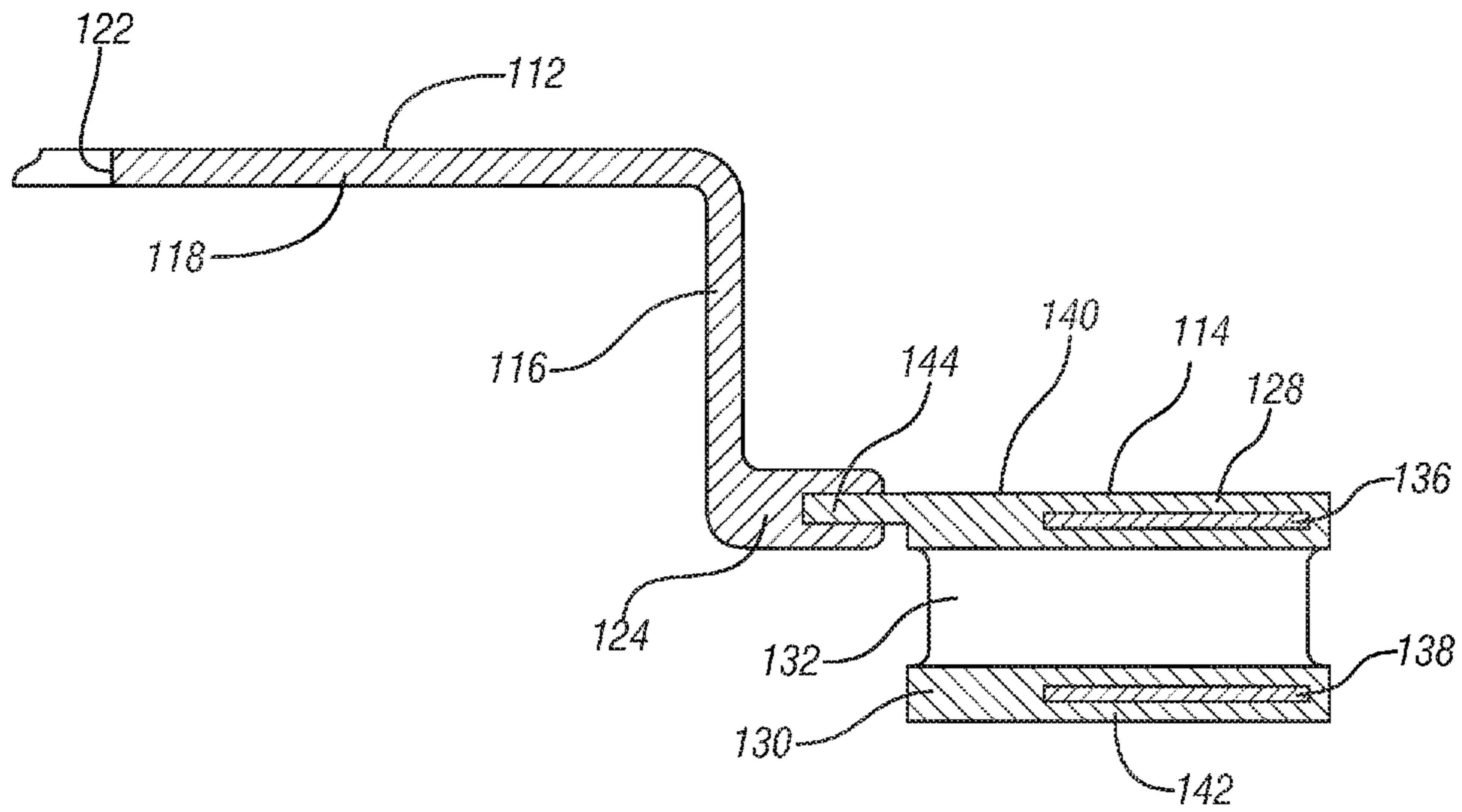


FIG. 3

## LOW MASS MULTI-PIECE SOUND DAMPENED ARTICLE

This application is a continuation-in-part of U.S. patent application Ser. No. 11/440,893, titled "Rotor Assembly and Method", filed May 25, 2006. This application claims the benefit of U.S. Provisional Application No. 60/956,452, titled "Low Mass Multi-Piece Sound Dampened Article", filed Aug. 17, 2007. The disclosures of the above applications are incorporated herein by reference.

### TECHNICAL FIELD

This disclosure pertains to a first article of a durable and relatively heavy material joined to a second article made of a lower density material. This disclosure illustrates an embodiment when the durable article is a ferrous metal annular brake rotor body comprising one or more inserts for coulomb friction damping, and the lighter weight part is an aluminum or magnesium alloy hub for the brake rotor.

### BACKGROUND OF THE INVENTION

Automotive vehicle disc brake rotors are an example of a manufactured article that may comprise a cast iron (or other durable, friction wear material) annular rotor body attached to a lower density metal hub. Of course, many other manufactured articles comprise, or could comprise, a relatively heavy and durable component that is subjected to loading stress and wear, and a lighter component serving another function.

In the case of the vehicle disc brake rotor, a hub is used to attach the rotor body to a vehicle wheel. The hub may be a round cylindrical body (sometimes shaped like a hat) attached to the wheel and aligned with the axis of rotation of the wheel. Attached to the bottom of the hat (for example) and extending radially outwardly is the annular rotor body or disc (brake frictional surface). In operation of the vehicle a hydraulically or electrically actuated brake caliper member, positioned around the outer circumferential edge of the rotor, presses friction pads against opposite sides (cheeks) of the annular rotor disc when it is desired to stop rotation of the wheel. The complimentary hub and rotor body portions of such brake rotors may be cast of a single metal alloy and formed as an integral article. Or the portion subjected to wear may be formed separately of a suitable metal composition and later attached to the complementary portion made of a lighter material. Thus, a complete and integral brake rotor may be formed, for example, of cast iron, or the rotor portion may be made of cast iron and the hub be made of an aluminum or magnesium alloy. An advantage of forming such an article of a relatively heavy and durable portion and a lighter material portion is the overall weight of the article may be reduced.

A brake disc is subject to frictional heating and to induced vibrations when brake pads are pressed against opposite cheeks of the rotating part. Accordingly, the annular rotor body portion of a disc brake may be formed with radial vents so that cooling air may be pumped through the rotating brake body. And sometimes it is desired to incorporate one or more annular inserts in the annular rotor body to produce coulombic friction between contacting surfaces of the embedded insert(s) and surrounding rotor body metal to dampen noise otherwise transmitted by the vibrating brake rotor. These additional structural features of the annular rotor body have significantly complicated the manufacture of low mass articles such as vented and sound dampened brake rotors.

### SUMMARY OF THE INVENTION

This disclosure pertains to multi-piece articles with immersed inserts in one of the pieces of the article.

In an embodiment of the disclosure, a multi-piece brake rotor is provided. In another embodiment of the disclosure the brake rotor comprises a hub formed of a cast low density metal alloy such as, but not limited to, an aluminum, titanium, or magnesium alloy. The hub is shaped for attachment to a vehicle wheel and for rotation coaxially with the wheel. The hub comprises a flange (e.g., a circumferential flange) for attachment to a radially extending annular rotor body with parallel radial faces (sometimes called cheeks) to be engaged by friction pads in a braking operation. The rotor body may be cast iron and may comprise at least one annular sound damping insert enclosed in the annular rotor body parallel to a brake cheek or radial face. The rotor body also comprises a flange portion or other structural feature for attachment with a hub in making the multi-piece brake rotor. The sound damping insert has at least one face in coulombic frictional contact with adjacent internal faces of the enclosing rotor body. The surfaces of the insert or of the body may have a coating of, for example, particulate material acting at the interfaces of the insert surface and body surface for enhancement of coulombic friction sound damping within the rotor body.

In another embodiment the rotor body may comprise radial vent passages defined by radial vanes separating two parallel annular body sections. In this embodiment the vanes and sandwiching body portions may be an integral cast body. In an embodiment of this type a sound damping insert may be located in either or both of the facing annular rotor body sections. The rotor body may have a circumferential edge surface characterized by the outer ends of the vanes the outer edges of the two parallel body portions and, if desired, the outer circumferential edge of a sound damping insert.

In another embodiment of the disclosure, the hub and rotor body are made separately and assembled such as by mechanical fasteners (e.g., bolts, rivets), or they may be cast separately and then welded together to make a brake rotor. For example, a hub may be cast of an aluminum alloy with a circumferential flange. Such a flange may have a round edge for engagement with a rotor body. Or the flange may have teeth or other projections for an interlocking attachment with a rotor body to withstand torsional forces produced at a hub-rotor body interface during vehicle braking.

In one embodiment, an annular rotor body (brake frictional surface) with one or more sound damping inserts may be made by a casting operation. For example, one or more stamped steel annular inserts with refractory or non-refractory particle surface coatings are positioned in a sand mold and sand core casting assembly providing casting cavity surfaces for forming the annular rotor body around the insert(s). Molten cast iron is poured into the mold, flowing around suitably anchored steel inserts and, upon cooling, an iron annular rotor body with integral embedded steel inserts is obtained. The cleaned and trimmed cast rotor body is ready for attachment to a hub. Overlapping or otherwise interconnecting hub and rotor body flanges may be bolted together through corresponding arcuately spaced holes in their flanges. Other attachment practices, such as welding, casting, or riveting, may also be used to rigidly attach the brake hub and annular rotor body pieces.

In other embodiment of the invention, an annular rotor body is prepared generally as described in the above paragraph. In this embodiment the rotor body flange is shaped for an interlocking or overlapping engagement with a subsequently cast hub formed of a lower melting point, lower density castable metal composition. The annular rotor body is placed in a supporting mold with a surrounding mold cavity defining the shape of a hub. When the hub alloy material is cast into the mold the hub is formed together with, for



example, a hub-flange shape that solidifies against a complementary rotor body flange that yields an interlocking connection between the hub and annular rotor body pieces of the brake rotor.

A practice of the invention has been illustrated in terms of a multi-piece brake rotor. However, it is clear that other multi-piece articles requiring a relatively heavy wear resistant part, including an enclosed insert, and a light weight part may be made by a similar practice. The result is an article of lower weight with good performance characteristics.

Accordingly, other objects and advantages of the content of this disclosure will become apparent from a further description of embodiment which follows with reference to drawings described in the following paragraph.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an oblique view of a multi-piece vehicle brake rotor which may be made in accordance with one embodiment of this disclosure.

FIG. 2 is radial cross-section of a portion of the bolted connection between the aluminum alloy hub and cast iron rotor of the assembled multi-part brake rotor illustrated in FIG. 1.

FIG. 3 is a radial cross-section, similar to the cross-section of FIG. 2, illustrating a cast-in-place attachment of an aluminum alloy hub section and a cast iron rotor section of a multi-piece brake rotor similar to the rotor illustrated in FIG. 1.

#### DESCRIPTION OF PREFERRED EMBODIMENTS

This disclosure illustrates multi-piece articles where one piece contains an immersed or embedded insert. A specific illustrative embodiment is of brake rotors of multi-piece construction comprising a hub and a rotor body. In an embodiment, the rotor body has vanes for air cooling of the rotor and the vented rotor body portions include one or two immersed coulomb friction damping inserts.

Many high performance vehicles use brake rotors with cast iron or steel friction surfaces joined to hub sections of lighter weight materials such as aluminum.

FIG. 1 illustrates a multi-piece brake rotor 10 which comprises hub 12 and rotor body 14. Hub 12 may be a casting made from a suitable aluminum alloy, or other light metal alloy, and rotor body 14 may be a casting made of cast iron with enclosed annular stamped steel insert bodies which will be described in more detail below. In one embodiment, the hub 12 and the annular rotor body 14 may be attached to each other with bolts or other suitable fasteners 26. Brake rotor 10 is adapted and shaped for attachment to a vehicle wheel and for braking of a wheel by engagement of friction pads (not shown) to side cheek surfaces of rotor body 14.

Hub 12 comprises a hollow cylindrical body 16 with an end surface 18. End surface 18 may comprise bolt holes 20 for attachment of brake rotor 10 to a vehicle wheel. End surface 18 may also comprise a central opening 22 for a vehicle axle. Attached to the other end of the hollow cylindrical body 16 is a radially outwardly extending hub flange 24. Hub flange 24 is attached to a flange 44 (better illustrated in FIG. 2) on rotor body 14 with bolts 26. In another embodiment, hub flange 24 is attached to flange 44 by welding.

Rotor body 14 is typically an integral iron casting that comprises an outboard rotor body portion 28 (outboard position when the brake rotor 10 is attached to a vehicle wheel), an inboard body portion 30 and radial vanes 32. Vanes 32 are

sandwiched between body portions 28, 30 to provide passages 34 for air flow when a wheel and attached rotor are rotating. In this embodiment of the disclosure, rotor body portions 28, 30 each contain an immersed cast-in-place annular stamped steel insert; insert 36 in body portion 28 and insert 38 in body portion 30. In other embodiments, only one of the rotor body portions 28, contains an insert.

FIG. 2 is an illustration of a radial cross-section of a multi piece brake rotor with an aluminum hub portion 12 joined with mechanical fasteners 26 to a cast iron or steel rotor 14. Rotor body portion 28 also has an integral, radially inwardly extending rotor body flange 44 which is rigidly attached to hub flange 24 by bolts 26. This mechanical connection between hub flange 24 and rotor body flange 44 maintains the structural integrity of brake rotor 10 despite torsional loading during vehicle braking.

Annular stamped steel insert 36 is seen to have flat, parallel upper and lower surfaces that lie generally parallel to friction surface 40 (cheek) of outboard body portion 28. Likewise, annular stamped steel insert 38 is seen to have flat, parallel upper and lower surfaces that lie generally parallel to friction surface 42 (cheek) of inboard body portion 30. Such coulomb damping inserts (36, 38) may be immersed or embedded in both rotor body portions 28, 30 or in either one of them. In various embodiments, the insert 36 may be formed of, for example but not limited to, aluminum, stainless steel, cast iron, any of a variety of other alloys, or metal matrix composite.

The annular surfaces of inserts 36, 38 typically have very small (microscopic) hills and valleys (which may be provided or enhanced by a suitable particulate coating, not shown) that interact with the enclosing iron body portions 28, 30 of the rotor to dampen vibrations produced in a revolving rotor by action of friction brake pads pressed against cheeks 40, 42 in braking of a vehicle wheel. In various embodiments, the inserts 36, 38 may have a suitable coating including, for example but not limited to, particles, flakes, or fibers including silica, alumina, graphite with clay, silicon carbide, silicon nitride, cordierite (magnesium-iron-aluminum silicate), mullite (aluminum silicate), zirconia (zirconium oxide), phyllosilicates, or other high-temperature-resistant particles. In various embodiments, the coating over the inserts 36, 38 may have a thickness of ranging from about 1  $\mu\text{m}$  to about 500  $\mu\text{m}$ .

FIG. 3 is an illustration of a radial cross-section of a multi piece brake rotor 110 with an aluminum hub portion 112 joined with a cast-in-place joint to a cast iron or steel rotor body 114.

Hub 112 comprises a hollow cylindrical body 116 with an end surface 118. End surface 118 may comprise a central opening 122 for a vehicle axle. Attached to the other end of hollow cylindrical body is a radially outwardly extending hub flange 124. Hub flange 124 is formed by casting hub 112 against and around complementary rotor body flange 144. For example, the rotor body 114 may be positioned in a lower tool, and the lower tool may be engaged with an upper tool to form a cavity. Molten material, for example but not limited to aluminum or magnesium alloy, is then introduced into the cavity to form the hub 112 with hub flange 124. Hub flange 124 is formed around and against rotor body flange 144 upon solidification of the molten alloy to form the complete hub shape. A strong cast-in-place bond is thus formed between the hub 112 and the rotor body 114.

As in the embodiment illustrated in FIG. 2, rotor body 114 is typically an integral iron casting that comprises an outboard rotor body portion 128, an inboard body portion 130 and radial vanes 132. Vanes 132 are sandwiched between body portions 128, 130 to provide passages for air flow when a



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wheel and attached rotor are rotating. Again, in this embodiment of the disclosure, rotor body portions **128**, **130** each contain an immersed cast-in-place annular stamped steel insert; insert **136** in body portion **128** and insert **138** in body portion **130**. Such coulomb damping inserts (**136** and **138**) may be immersed in both rotor body portions **128**, **130** or in either one of them.

In each of the above examples, the rotor could be a non-vented type that does not include vanes **32** or **132** but has a single solid body portion with at least one coulomb friction damping insert.

Practices of the invention have been shown by examples that are presented as illustrations and not limitations of the invention.

The invention claimed is:

**1.** A multi-piece, sound dampened brake rotor for attachment to a vehicle wheel, the rotor comprising;

a hub with a round cylindrical body with a partial closure at one end of the cylindrical body providing for attachment of the brake rotor to a vehicle wheel, and a radially outwardly extending hub flange from the cylindrical body; and an annular rotor body comprising a radially internal circumferential surface with a flange, the body extending to an external diameter with an external circumferential surface and having parallel opposing body surfaces for frictional engagement in braking of the vehicle wheel, the rotor body comprising at least one

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annular insert between the parallel body surfaces and constructed and arranged to provide coulomb friction damping; the hub flange and annular rotor body flange are attached to form the brake rotor and to withstand torsional forces arising from vehicle braking, in which the annular insert has a coating comprising at least one of silica, alumina, graphite with clay, silicon carbide, silicon nitride, cordierite (magnesium-iron-aluminum silicate), mullite (aluminum silicate), zirconia (zirconium oxide), phyllosilicates, or other high-temperature-resistant particles.

**2.** A multi-piece, sound dampened brake rotor for attachment to a vehicle wheel, the rotor comprising; a hub with a round cylindrical body with a partial closure at one end of the cylindrical body providing for attachment of the brake rotor to a vehicle wheel, and a radially outwardly extending hub flange from the cylindrical body; and an annular rotor body comprising a radially internal circumferential surface with a flange, the body extending to an external diameter with an external circumferential surface and having parallel opposing body surfaces for frictional engagement in braking of the vehicle wheel, the rotor body comprising at least one annular insert between the parallel body surfaces and constructed and arranged to provide coulomb friction damping; further comprising a coating comprising refractory particles over the insert.

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